Prototyping of the ESMF with DOE's CCA

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Outline

- Purpose
- Background of Common Component Architecture (CCA)
- Relationship among climate models, CCA, and ESMF.
- ESMF-CCA Prototype
- Demo
- Summary

Purpose

- Identify any major obstacles in ESMF development and find potential solutions.
- Given Earth system models developed under the Earth System Modeling Framework (ESMF), we will find out what is needed to make those models CCA-compliant.
- Use a CCA-compliant framework such as Ccaffeine to assemble components from various organizations and perform the calculations/simulations.

Common Component Architecture (CCA)
Background

- Goal: Interoperability between components developed by various groups/organizations.
- Define specifications for high-performance scientific components & framework.
- Provide frameworks such as Ccaffeine to support CCA-compliant components.

CCA Background (Continued)

- Existing component architecture standards, such as CORBA, COM/DCOM, and JavaBeans/EJB, are widely used in commercial industry.
- They do not support efficient parallel communication channels between components.

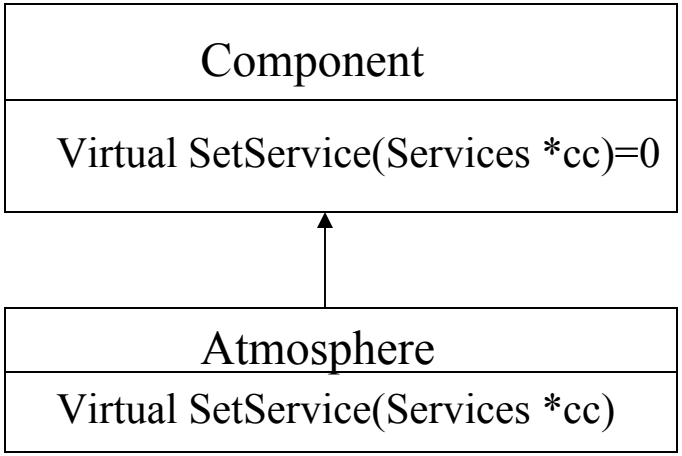
CCA Background (Continued)

- Existing high-performance frameworks such as POOMA and Overture are object-oriented, not based on peer components where components are viewed as equal participants rather than as elements in an inheritance hierarchy.
- They provide many supporting utilities and are restricted to a particular scientific or numerical domain. For example, Overture is used mostly for solving PDE in structured grids.

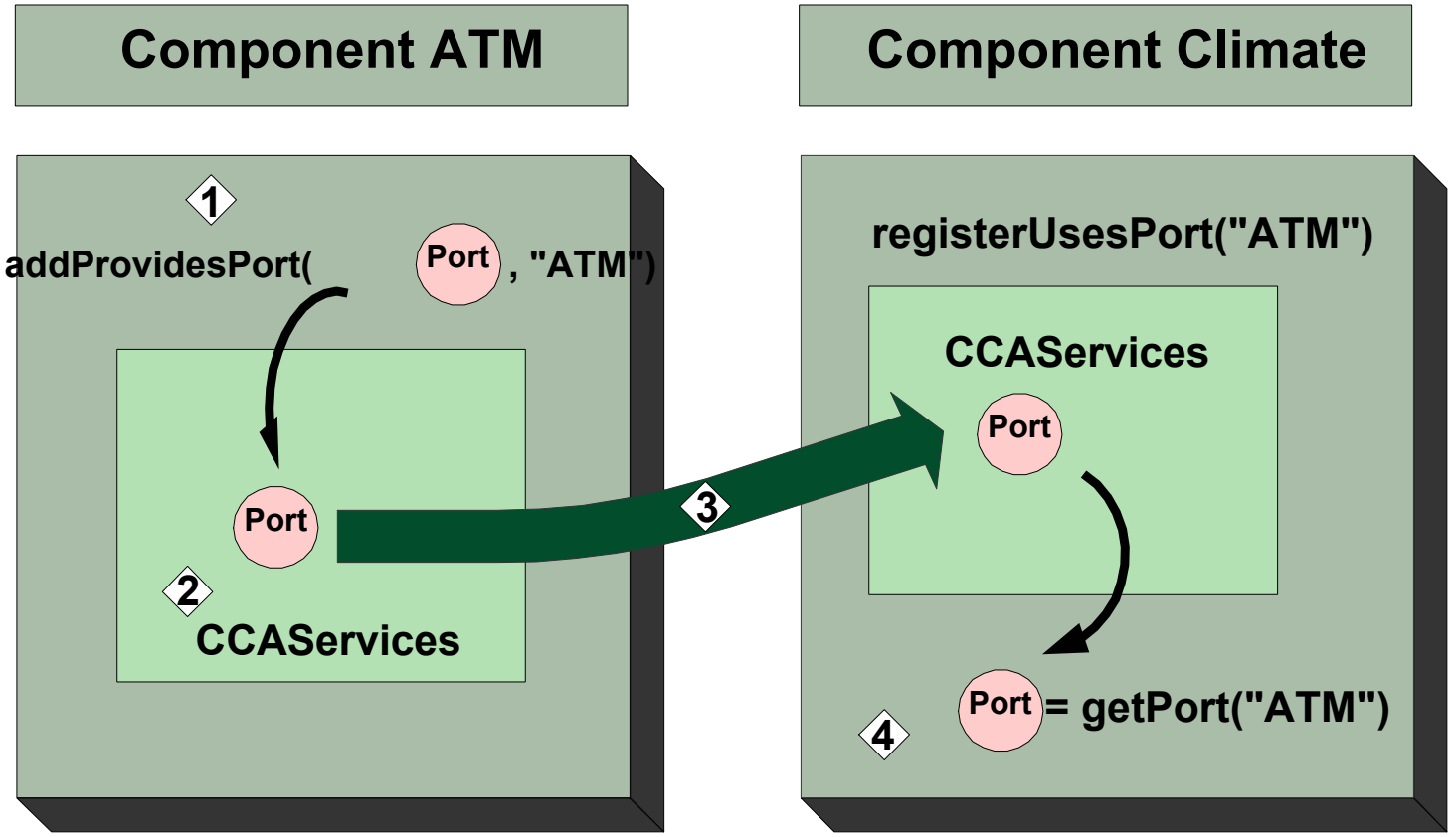
What is CCA-Compliant Component

- A component needs to inform CCA framework what ports it provides and what ports it uses.
- Through the CCA framework, a component knows what ports other components provide, gets needed ports, and uses their functions.

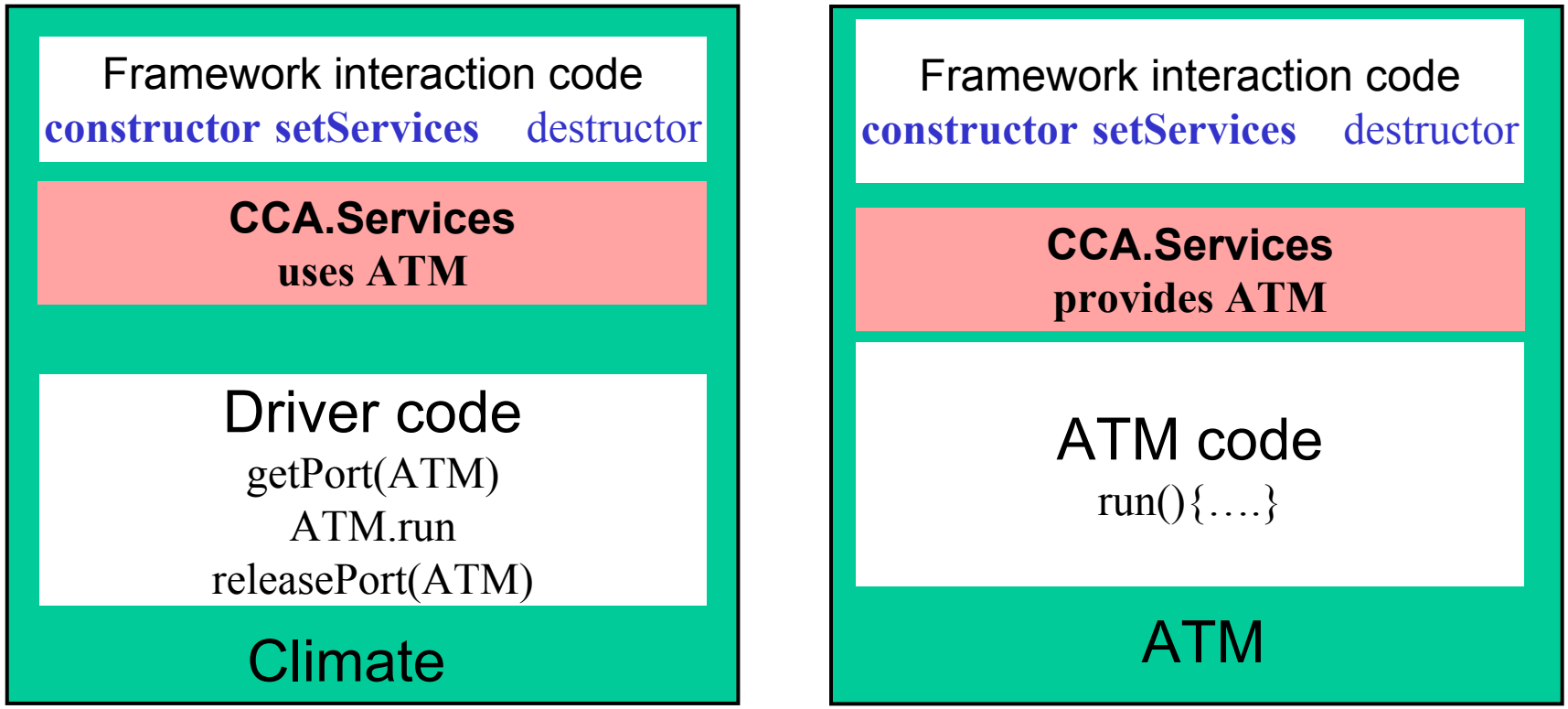
Compliant Requirement:
Override one method of base class:setService(…)



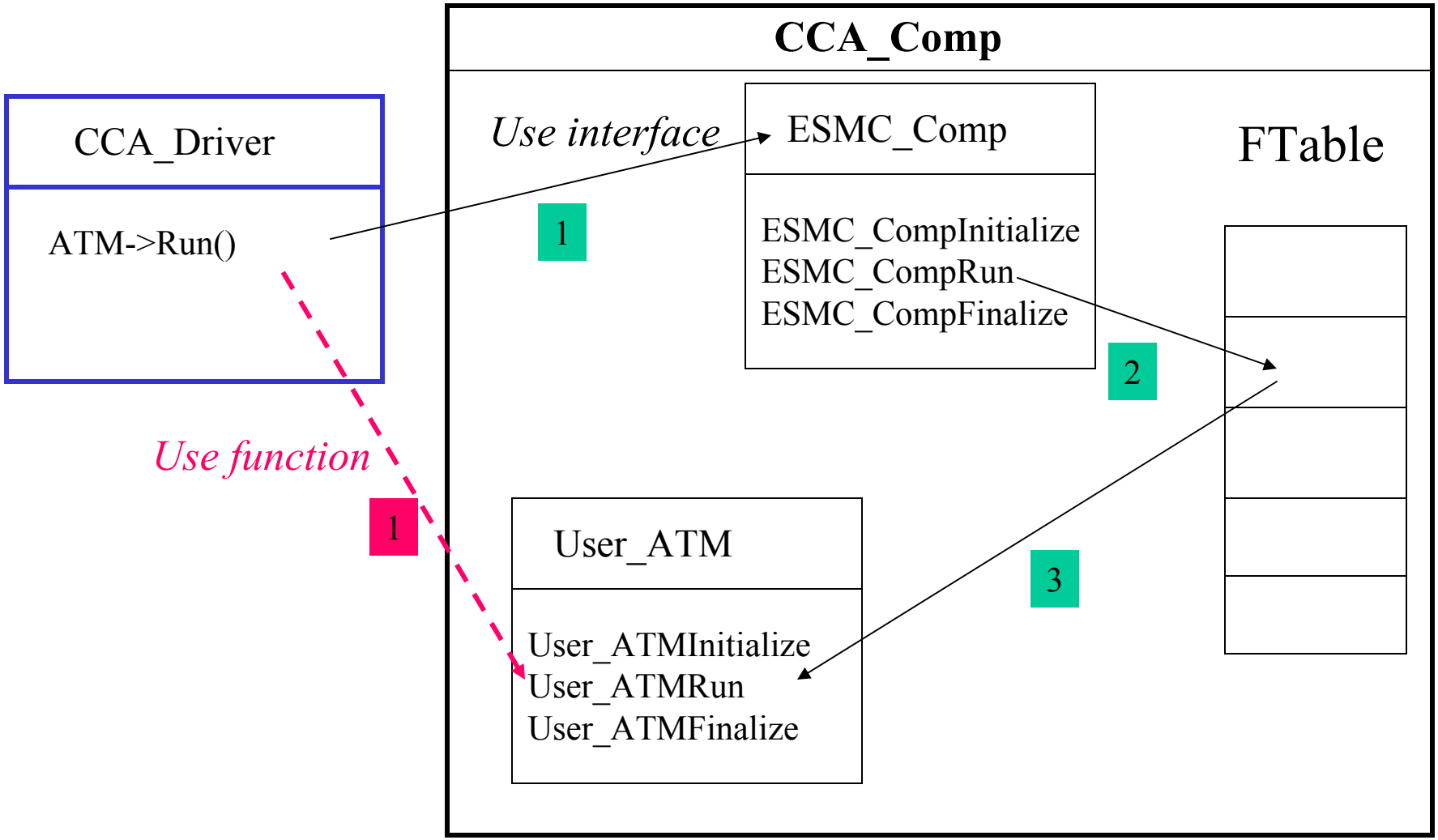
CCA Ports and the Provides/Uses Design Pattern for Coupling Components is Simple and Flexible



Framework Mediates Component Interactions



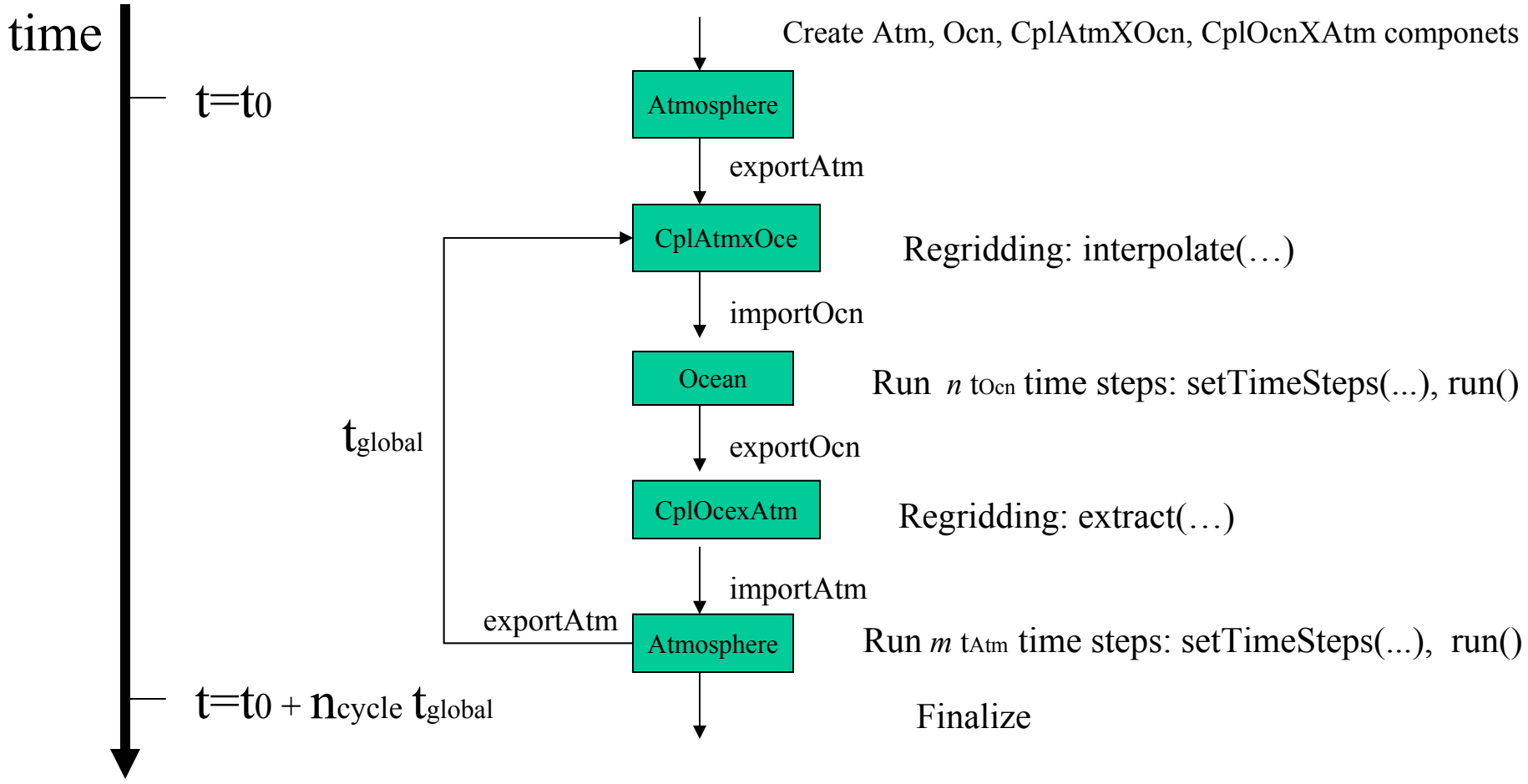
Use an ESMF Component in CCA



The Relationship among Climate Models, CCA, and ESMF

- CCA provides a generic way of supporting component interaction.
- ESMF specifies how climate model components will interact.
- Using a typical flow diagram for atmosphere-ocean coupling to show the relationship among models, CCA, and ESMF.

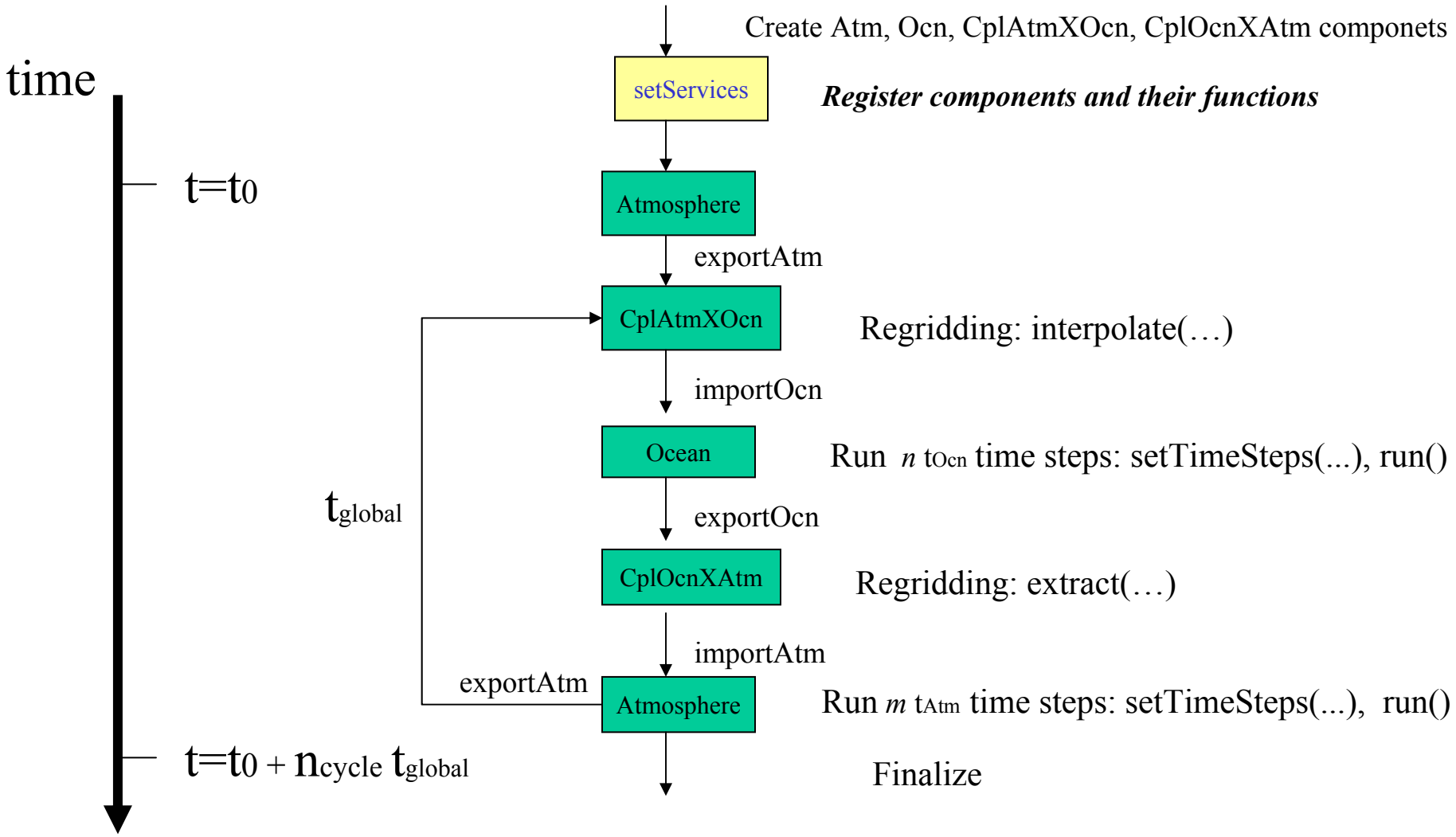
Flow Diagram of Coupling Atmosphere and Ocean (a Sequential Coupling without Framework)



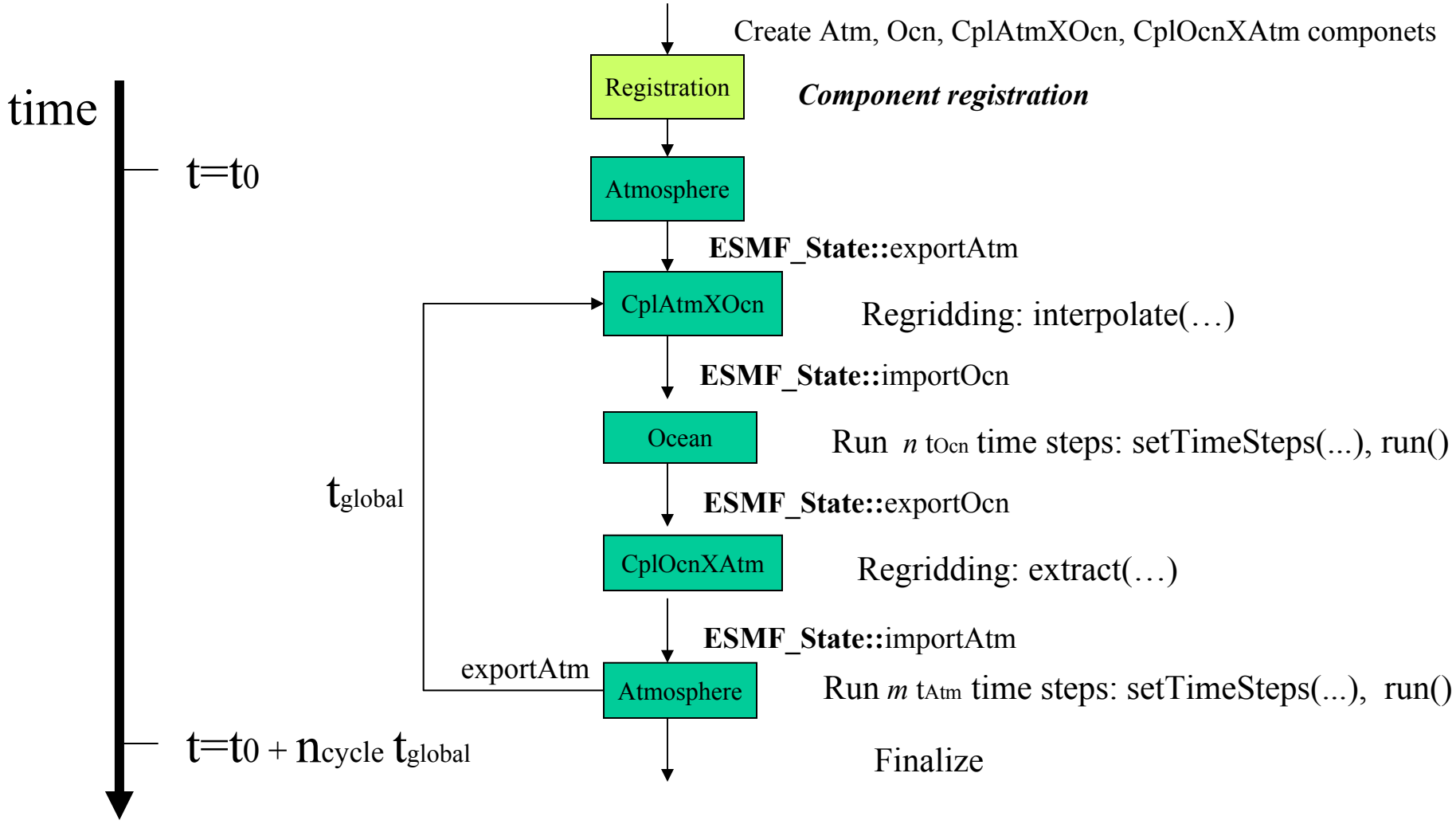
Note: t_{global} is the time advance in one coupling cycle

n_{cycle} is the number of cycle.

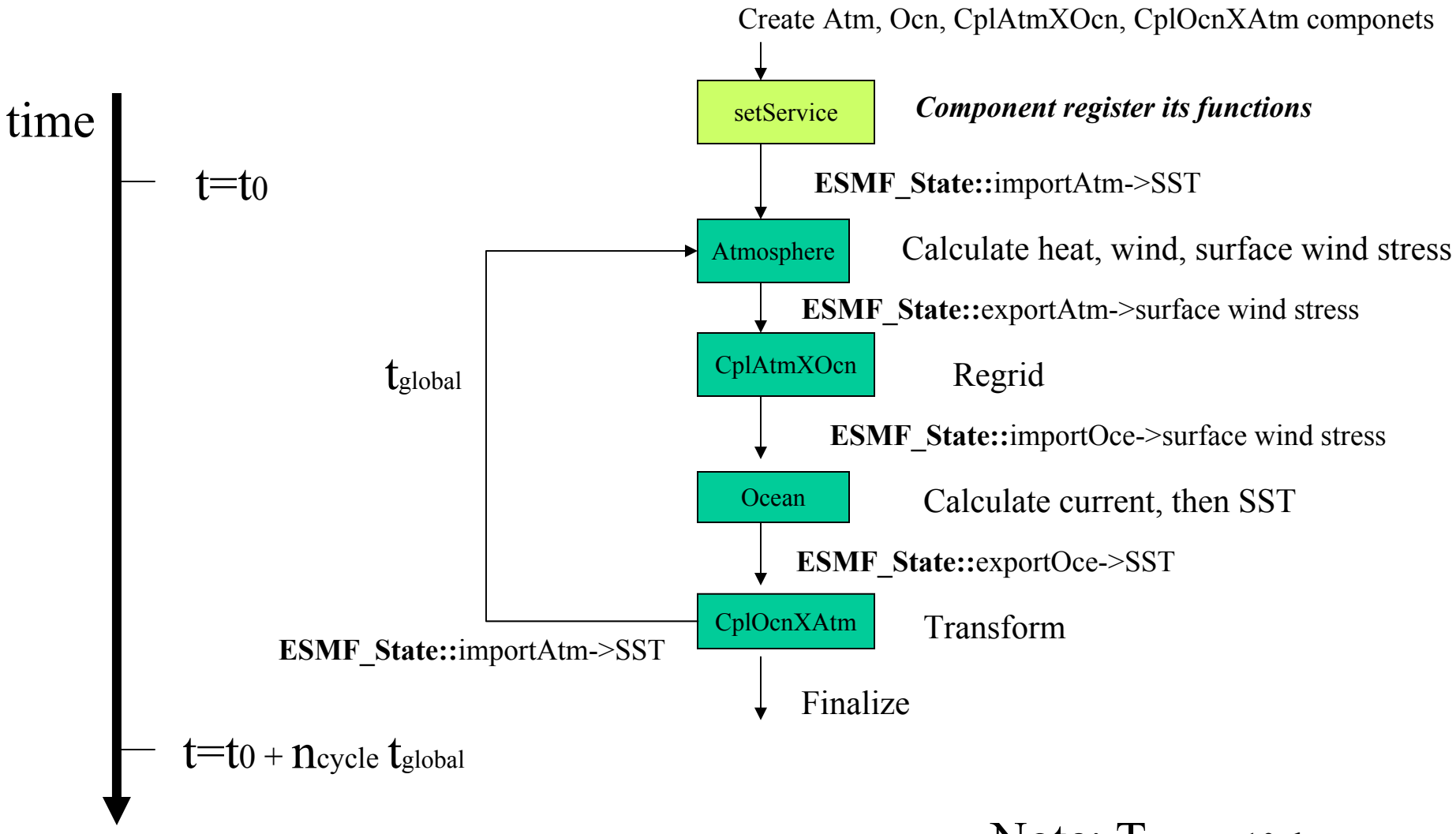
Flow Diagram of Coupling Atmosphere and Ocean (a Sequential Coupling in CCA)



Flow Diagram of Coupling Atmosphere and Ocean (a typical ESMF application)



Flow Diagram of Coupling Atmosphere and Ocean (Cane-Zebiak Model, well-known for predicting *El Nino* events)



Note: T_{global} = 10 days

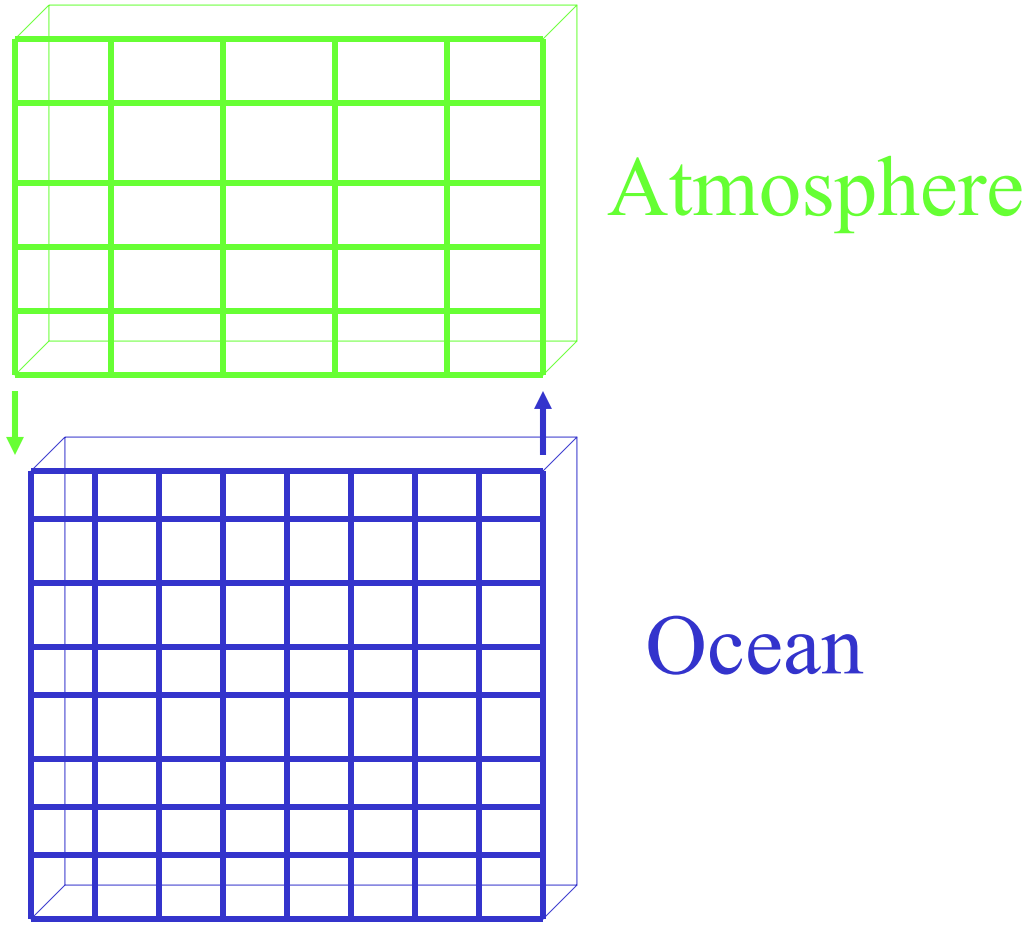
ESMF-CCA Prototype's Relationship with ESMF and CCA

- The prototype adopts:
  - CCA's registration (setService)
  - CCA's component connection GUI.
  - Data is exchanged in a similar manner to ESMF_State
  - Standard functions of ESMF's component
    - Initialize()
    - Run()
    - Finalize()

Simulation Description

- Atmosphere component
  - Initial condition: zero field
  - 16x16 grid points
  - Run 5 timesteps in each coupling cycle
- Ocean component
  - Initial condition: Gaussian distribution
  - 31x31 grid points
  - Run 1 timestep in each coupling cycle
- Climate component (Driver)
  - Run 10 coupling cycles

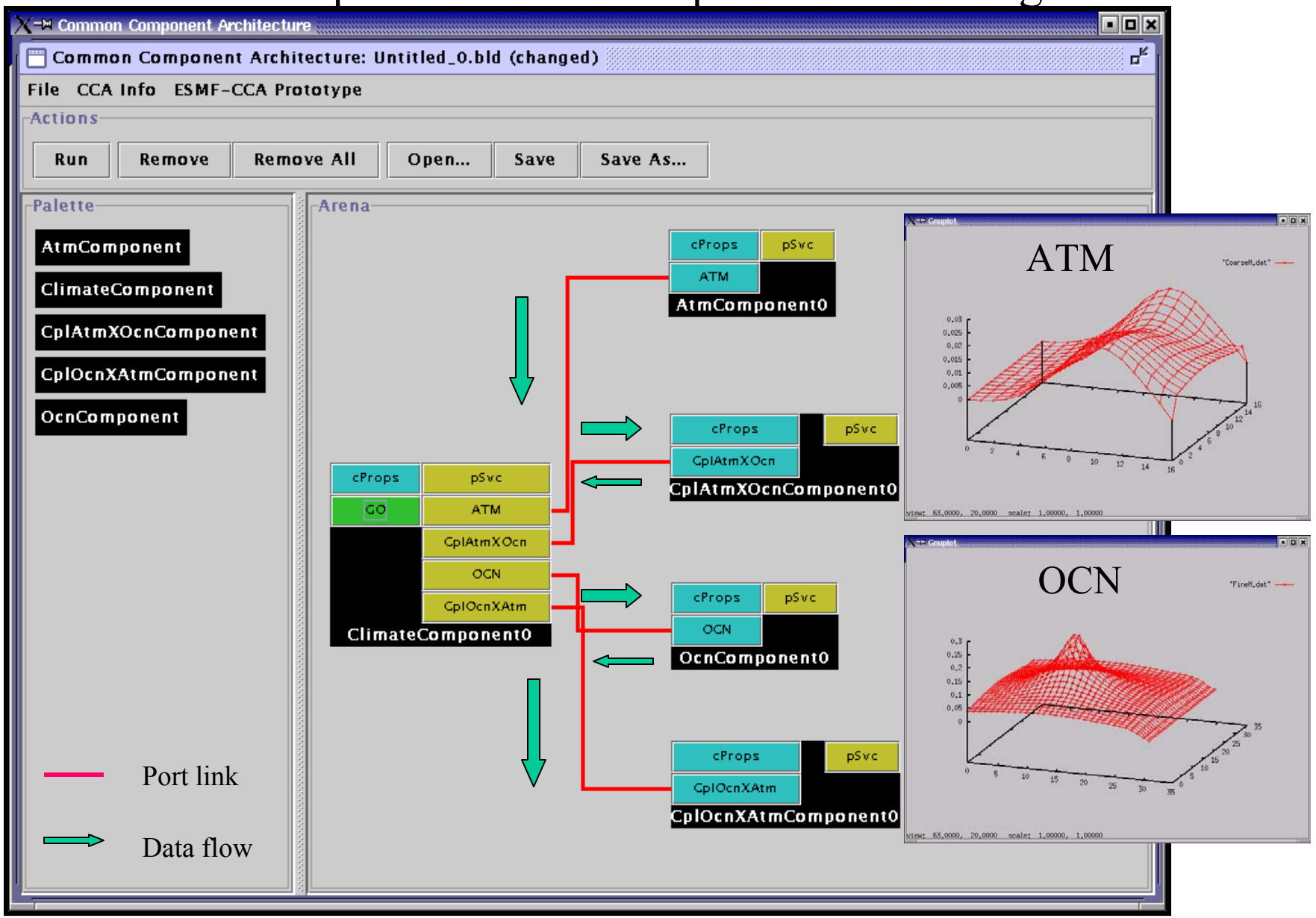
2D Coupled Atmosphere-Ocean Model



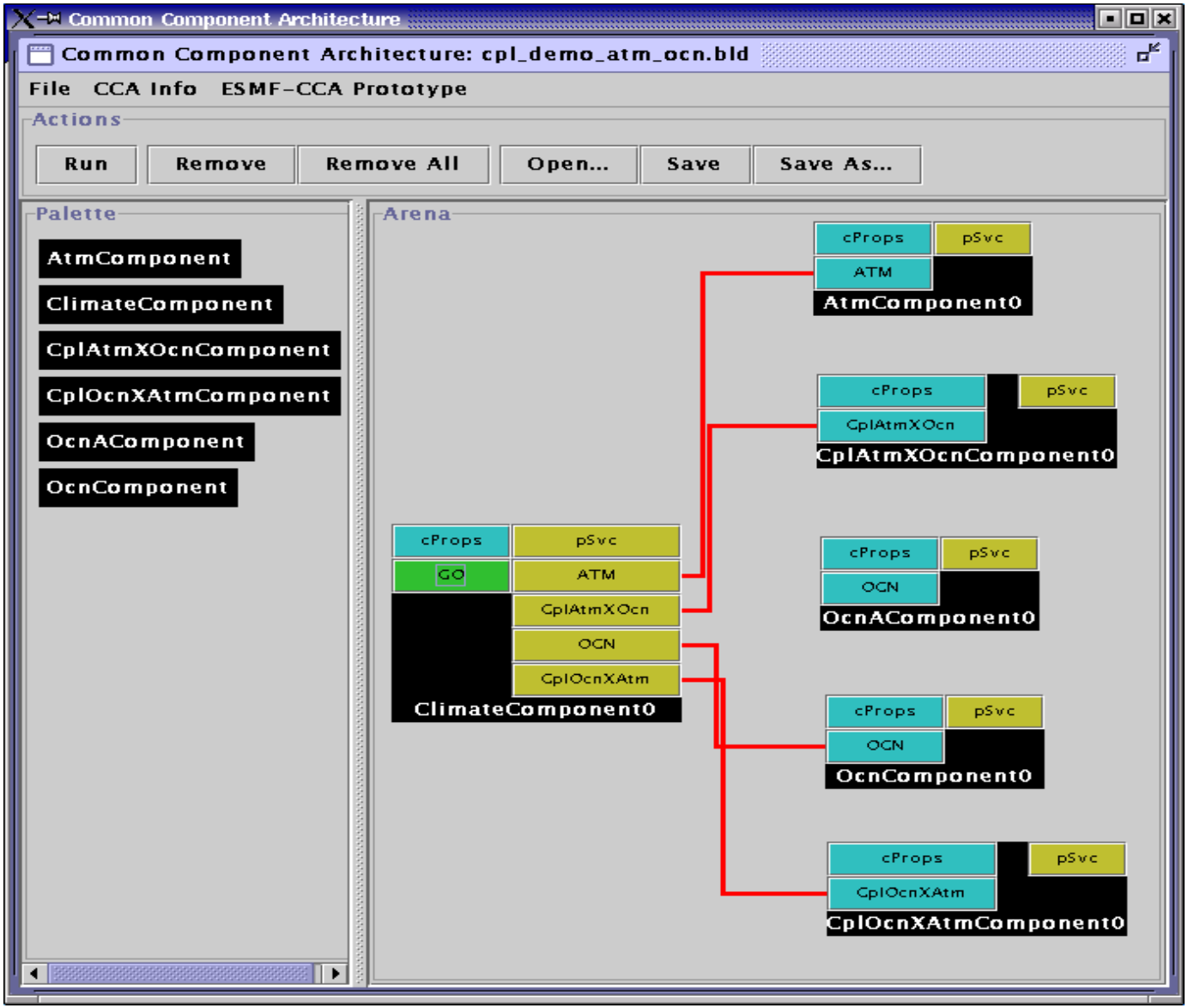
Minimum Requirement for a Software: **Run**

- Three cases:
  - Coupling with ocean, atmosphere, atmosphere-to-ocean coupler, and ocean-to-atmosphere coupler.
  - Replacing ocean with a different one with the same interface.
  - Replacing atmosphere with a coupled atmosphere-analysis component.

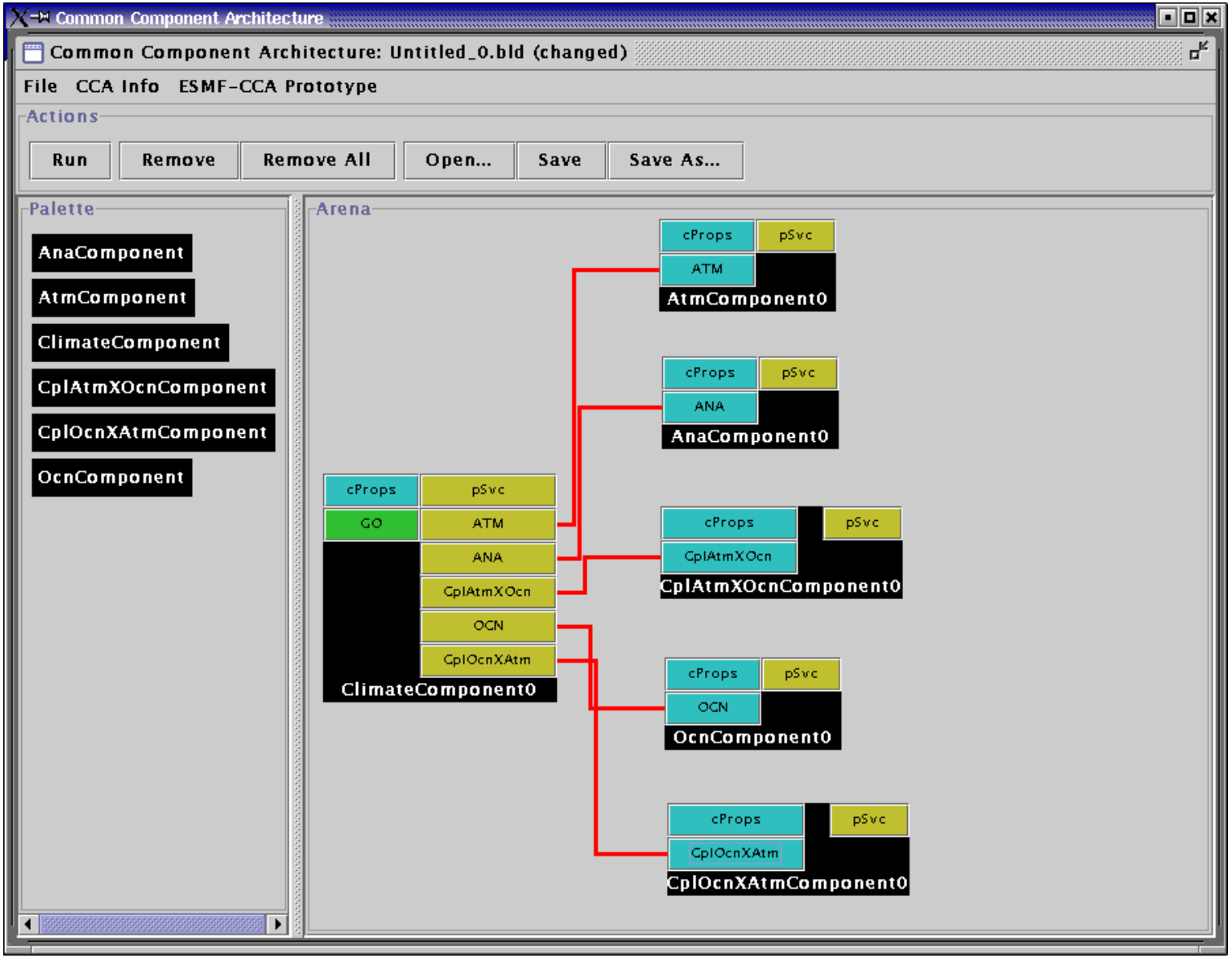
Component Relationship via CCA Wiring



ESMF-CCA Prototype Including Two Ocean Components



ESMF-CCA Prototype Including Data Assimilation Component



Next step

- Make the intermediate coupled atmosphere-ocean model, Cane-Zebiak model, run in ESMF as well as CCA.

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Componentization of Cane-Zebiak Model

F77 Subroutines

cforce

ssta

zatmc

mloop

stress

getn

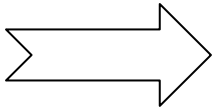
zavg

zqgen

fft2c

trid

...



Components

Atmosphere

CplAtmXOcn

Ocean

CplOcnXAtm

Summary

- Common Component Architecture (CCA) provides a flexible way of supporting model components.
- CCA can support ESMF-compliant components.